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Asarum majale (Aristolochiaceae), a New Species from the Suzuka Mountain Range, Kinki District, Japan

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A new species, *Asarum majale* T. Sugaw., is described from north of the Suzuka Mountains, Kinki District, Japan. *Asarum majale* is allied to *A. fauriei* var. *takaoi*, which has a wide distribution from Kinki to Hokuriku and the southwestern part of Chubu District, and also to *A. dilatatum*, which is restricted to Mt. Nonobori to the south of the Suzuka Mountains. *Asarum majale* is distinguished from them by the larger calyx tube, longer anthers, gynoecium positioned lower than the entrance to the calyx tube, and anthesis from mid to late May. *Asarum majale* occurs at the foot of Mt. Fujiwara-dake, Mt. Fukuo-zan and Mt. Nihon-koba.

Key words: Aristolochiaceae, *Asarum, Asarum majale*, Kinki District, morphological variation, new species, Suzuka Mountains

Asarum L. is a diverse genus of perennial herbs occuring in eastern Asia, Europe and North America (Kelly 1998). The genus is especially diversified in the Japanese Archipelago, where 50 species have been recognized (Sugawara 2006). Although many investigators (Maekawa 1932, 1933, Hatusima & Yamahata 1988, Sugawara 1992, 1998, 2003) have tried to clarify and enumerate the Japanese species, the taxonomy of Japanese *Asarum* is still incomplete.

During our examination of *Asarum* from the foot of Mt. Fujiwara-dake and adjacent areas in the Suzuka Mountains, Kinki District, Japan, we found unrecognizable plants in which the flowers open from mid to late May. The plants bore orbicular to orbicular-ovate leaves and campanulate flowers with a widely opened calyx tube entrance. In the Suzuka Mountains and adjacent areas, four taxa of *Asarum*, *A. asperum* F. Maek. var. *asperum*, *A. rigescens* F. Maek. var. *brachypodion* T. Sugaw., *A. dilatatum* (F. Maek.) T. Sugaw. and *A. fauriei* Franch. var. *takaoi* (F. Maek.) T. Sugaw., assigned to section *Heterotropa* (Morr. & Decne.) A. Braun (Kelly 1998), were already known (Maekawa 1933, Kitamura & Murata 1961, Satake & Momiyama 1982, Murata 1982). Their flowering seasons are usually as follows: *A. asperum* flowering March to April, *A. rigescens* var. *brachypodion* flowering January to March, *A. dilatatum* flowering October to November and *A. fauriei* var. *takaoi* flowering mainly February to March (Satake & Momiyama 1982, Sugawara, 2006). In comparison with these and other taxa within the section, the unrecognized plants were unique in their flowering season and were easily distinguished from *A. asperum* and *A. rigescens* var. *brachypodion* in the shape of the calyx tube and in leaf morphology (Maekawa 1932, Satake & Momiyama 1982, Sugawara 2006). The unknown plants bore some resemblance to *A. dilatatum* and *A. fauriei* var. *takaoi* in the shape of the leaf and in the widely opened entrance of the calyx tube. In earlier reports (Kitamura & Murata 1961, Satake & Momiyama 1982), *A. dilatatum* and *A. faurieri* var. *takaoi* were treated as infraspecific taxa of the same species despite the differences in flowering season. The plants of the unknown *Asarum* from Mt. Fujiwara-dake, although previously collected, were considered to be *A. dilatatum* or *A. fauriei* var. *takaoi* (Murata 1982).

To clarify the taxonomic disposition of the unknown May-flowering plants, population samples of them and of *Asarum dilatatum* and *A. fauriei* var. *takaoi* were compared morphologically with the result that we determined them to be specifically distinct and here describe them as new.

Asarum majale T. Sugaw., **sp. nov.** (Figs. 1, 3A)
Haec species *Asaro dilatato* et *A. fauriei* var. *takaoi* valde affinis est, sed tubo calycis majore, antheris longioribus, anthese majali facile distinguitur.

Typus: JAPAN, Mie Pref., Inabe-gun, Fujiwara-cho, Sakamoto, at the foot of Mt. Fujiwara-dake, alt. 250 m, 25 May 2001, *T. Sugawara & K. Taniwaki 1052501* (holotype: MAK 368765; Isotype: TI) .

Perennial herbs. **Rhizomes** short. **Leaf** blade orbicular to widely ovate, 4-7 cm long, 4-6 cm wide, base cordate, apex rounded or slightly acute; upper surface dark green to green, usually lusterless, variegated or not, sparsely pubescent; lower surface pale green, glabrous; petiole dark purple, glabrous, 5-13 cm long. **Pedicel** 5-10 mm long. **Flowers**, solitary, axillary, opening mid to late May; decumbent; calyx greenish purple or pale brown; calyx tube campanulate, 7.5-11 mm long, 9-13 mm wide, throat with a narrow orifice ring, opening widely, 6-9 mm in diam., inner surface usually complicatedly reticulated, with longitudinal and transverse ridges, longitudinal ridges usually 15-21, transverse ridges 3-5; limb 3 lobed; calyx lobes obliquely spreading, triangular, apex slightly acute, 7-10 mm long, upper surface relatively smooth, lower surface smooth and glabrous; stamens 12, in 2 whorls of 6, free to base, subsessile, 2.5-3.5 mm long; filaments less than 0.5 mm long; anthers extrorse, longitudinally dehiscing, 2-3 mm long; connectives slightly prominent or not; ovary superior, 6-celled; styles 6, free, erect, apex with horn-like protuberance; protuberances usually 1.2-2.2 mm long, extending nearly to calyx tube entrance but not exserted from entrance; stigma elliptic, extrorse.

Japanese name: Kotô-kan-aoi

Distribution: Japan, Kinki District, Shiga & Mie Pref., North of Suzuka Mountains at foot of Mt. Fujiwara-dake, Mt. Fukuo-zan and Mt. Nihon-koba.

Other specimens examined: **JAPAN: HONSHU; Mie Pref.,** Inabe-gun, Fijiwara-cho, Mt. Fujiwara-dake, 16 May 1937, *S. Sonoda* (KYO); Mt. Fujiwara-dake, *N. Fukuoka 4774* (KYO); Mt. Fujiwara-dake, *T. Sugawara* (MAK 197339); Mie-gun, Komono-cho, Taguchi, at the foot of Mt. Fukuo-zan, alt. 260 m, *T. Sugawara & K. Taniwaki 1052502* (MAK 369653); **Shiga Pref.,** Kanzaki-gun, Eigenji-cho, Yuzurio, alt. ca. 400 m, *N. Fukuoka 4772* (KYO); Nakahata, at the foot of Mt. Nihon-koba, alt. 400 m, *T. Sugawara 1060401* (MAK 369652).

Materials and Methods

Three populations of the May flowering *Asarum majale* were collected in Kinki District, north of the Suzuka Mountains at the foot of Mt. Fujiwara-dake, Mt. Fukuo-zan and Mt. Nihon-koba (Fig. 1; Table 1, see also Fig. 2). The plants were usually in broad-leaved evergreen forests dominated by *Quercus glauca* Thunb. and *Q. myrsinifolia* Blume. We also studied one population of *A. dilatatum* from Mt. Nonobori, south of the Suzuka Mountains (Satake & Momiyama 1982). *Asarum fauriei* Franch. consists of four infraspecific taxa, var. *fauriei*, var. *nakaianum* (F. Maek.) Ohwi, var. *takaoi* (F. Maek.) T. Sugaw. and var. *stoloniferum* (F. Maek.) T. Sugaw.

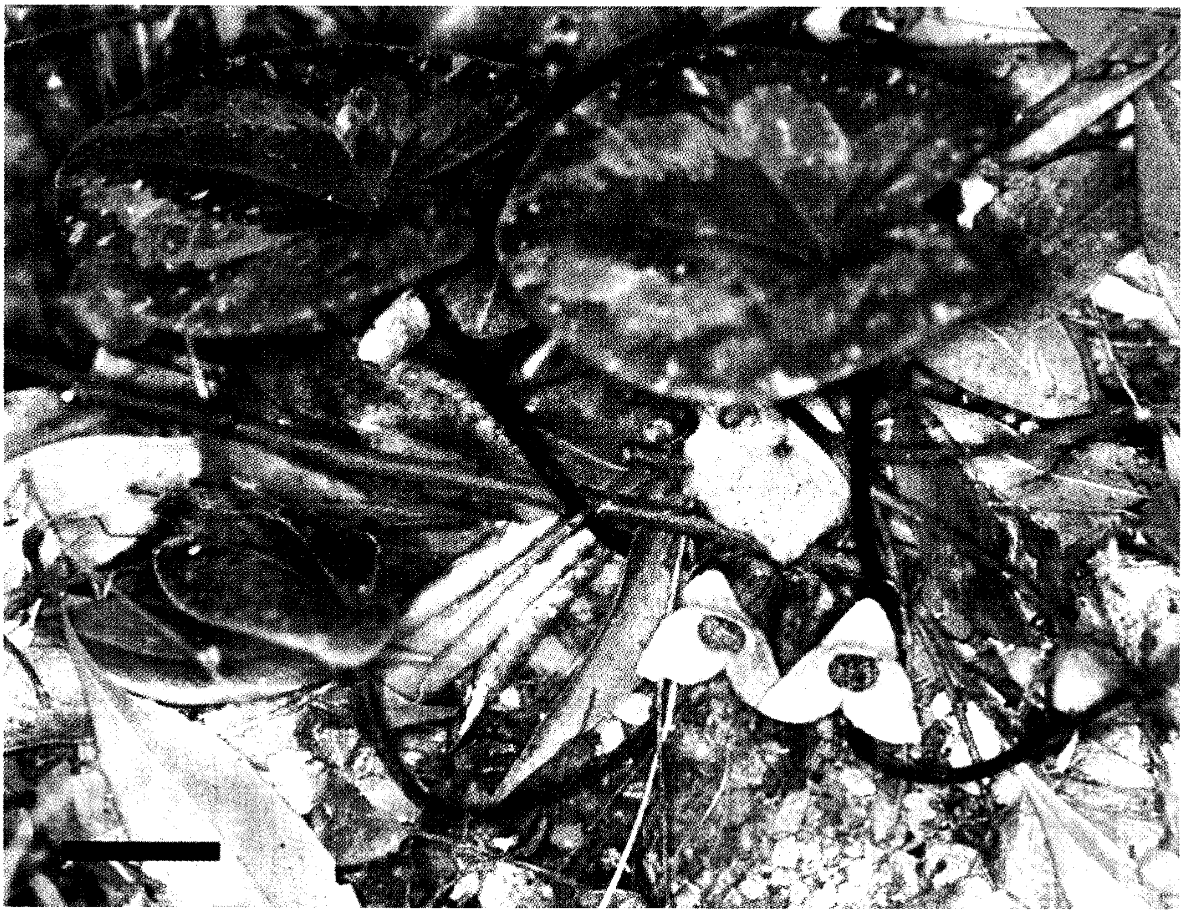

FIG. 1. *Asarum majale* from north of the Suzuka Mountains at foot of Mt. Fujiwara-dake. Two flowers open on ground. Scale bar = 20 mm.

(Sugawara 2006). Of the four, varieties *fauriei* and *nakaianum* occur in deciduous forests in the northern part of the Chubu and northern Tohoku Districts (Sugawara 2003). They are characterized by having smaller leaves and a shorter calyx tube with longer stylar protuberaces than the two others. Var. *stoloniferum*, known only as a garden cultivar, is characterized by having markedly impressed leaves. Var. *takaoi* usually occurs in evergreen broad-leaved forests in Kinki, Hokuriku Districts and southwestern Chubu Districts (Hiura 1977). Because of similarities in geographical distribution and gross morphology, we compared *A. majale* with *A. faurei* var. *takaoi*. We selected 10 populations of var. *takaoi* located within the Kinki, Hokuriku, and Chubu Districts (Table 1, see also Fig. 2). The number of individuals examined in each population is shown in Table 1. Representative voucher specimens of each population were deposited in the Makino Herbarium (MAK), Tokyo Metropolitan University, Tokyo.

In all population samples the following characters were measured: calyx tube length (a), calyx tube width (b), diam. of calyx tube entrance (c), calyx lobe length (d), calyx lobe width (e), length of stylar protuberance (f), length of anthers in outer whorl (g), number of longitudinal ridges on inner surface of a calyx tube (h), leaf length (i), and leaf width (j). For floral parts, flowers collected from native habitats were fixed in FAA and were then measured with the aid of a binocular microscope following the procedures of Sugawara (2003). The morphological features include characters determined to be diagnostic in past studies and newly

TABLE 1. Collection sites, number of plants examined, and voucher specimens for observation of morphological characters.

Population number and locality (Number of plants examined)	Voucher specimens deposited in MAK
A group of May flowering plants (= *Asarum majale*)	
1. Mie Pref.: Mie-gun, Komono-cho, Taguchi, foot of Mt. Fukuo-zan, alt. 260 m (12)	*TS&KT1052502*
2. Mie Pref.: Inabe-gun, Fujiwara-cho, Sakamoto, foot of Mt. Fujiwara-dake, alt. 250 m (12)	*TS&KT1052501*
3. Shiga Pref.: Kanzaki-gun, Eigenji-cho, Nakahata, foot of Mt. Nihonkoba, alt. 400 m (6)	*TS1060401*
Asarum dilatatum	
4. Mie Pref.: Suzuka-shi, Mt. Nonobori, alt. 500 m (16)	*TS1101201*
Asarum fauriei* var. *takaoi	
5. Mie Pref.: Ueno-shi, Iga-ueno, alt. 170 m (5)	*TS1030101*
6. Mie Pref.: Ueno-shi, Osada, alt. 180 m (12)	*TS4031701*
7. Mie Pref.: Ueno-shi, Shimagahara, alt. 180 m (12)	*TS4031702*
8. Mie Pref.: Toba-shi, Toba, alt. 80m (14)	*TS940210*
9. Gifu Pref.: Masuda-gun, Kanayama-cho, Asotani, alt. 320 m (8)	*TS1032401*
10. Gifu Pref.: Masuda-gun, Kanayama-cho, Yakeishi, alt. 300 m (10)	*TS940410*
11. Fukui Pref.: Sakai-gun, Kanazu-cho, Kumasaka, alt. 60 m (15)	*TS3030901*
12. Ishikawa Pref.: Enuma-gun, Yamanaka-cho, Hannyaiwa, alt. 200 m (14)	*TS980320*
13. Nagano Pref.: Shimoina-gun, Ookuwa-mura, Ogawa, alt. 600 m (12)	*TS970302*
14. Nagano Pref.: Shimoina-gun, Nagiso-machi, Godo, alt. 400 m (9)	*TS970304*

TS&KT: collected by T. Sugawara and K. Taniwaki. TS: collected by T. Sugawara.

added characters suspected to have taxonomic value.

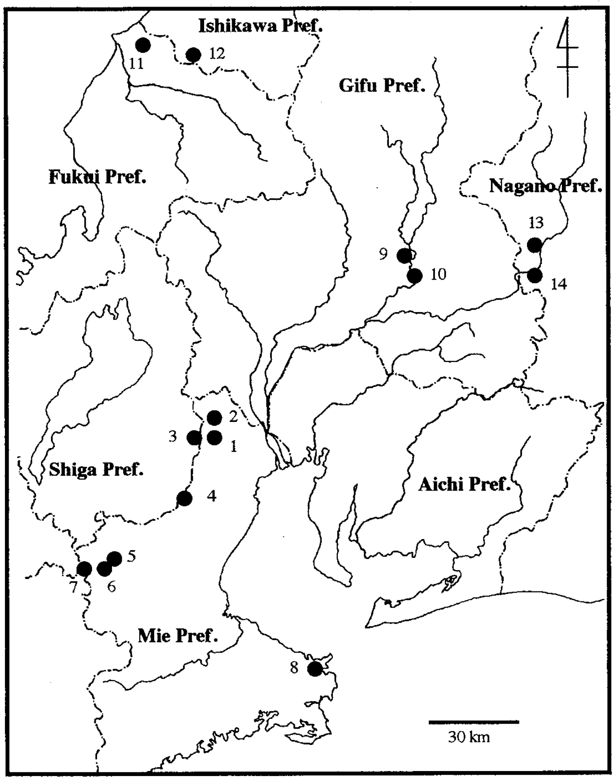

FIG. 2. Map showing localities of 14 populations of *Asarum majale*, *A. dilatatum* and *A. fauriei* var. *takaoi* examined in central Honshu, Japan. Population numbers correspond to numbers in Table 1.

Results and Discussion

Morphological variation in Asarum majale, A. dilatatum *and* A. fauriei *var.* takaoi

Representatives of *Asarum majale, A. dilatatum* and *A. fauriei* var. *takaoi* are shown in Fig. 3. Despite paying particular attention to floral and leaf characters regarded as being useful in distinguishing the species examined, we found considerable variation in floral and leaf morphology between and even within populations, and no discreet gaps in each of the 10 floral and leaf characters examined.

To determine if the three taxa can be divided into taxonomic groups, data on seven floral characters were obtained from 157 individuals and subjected to principal component analysis. The first three principle components explain 86.2% of the total variation with 43.5%, 23.6% and 19.1% for the respective axes (Table 2). Calyx tube width (+0.4842

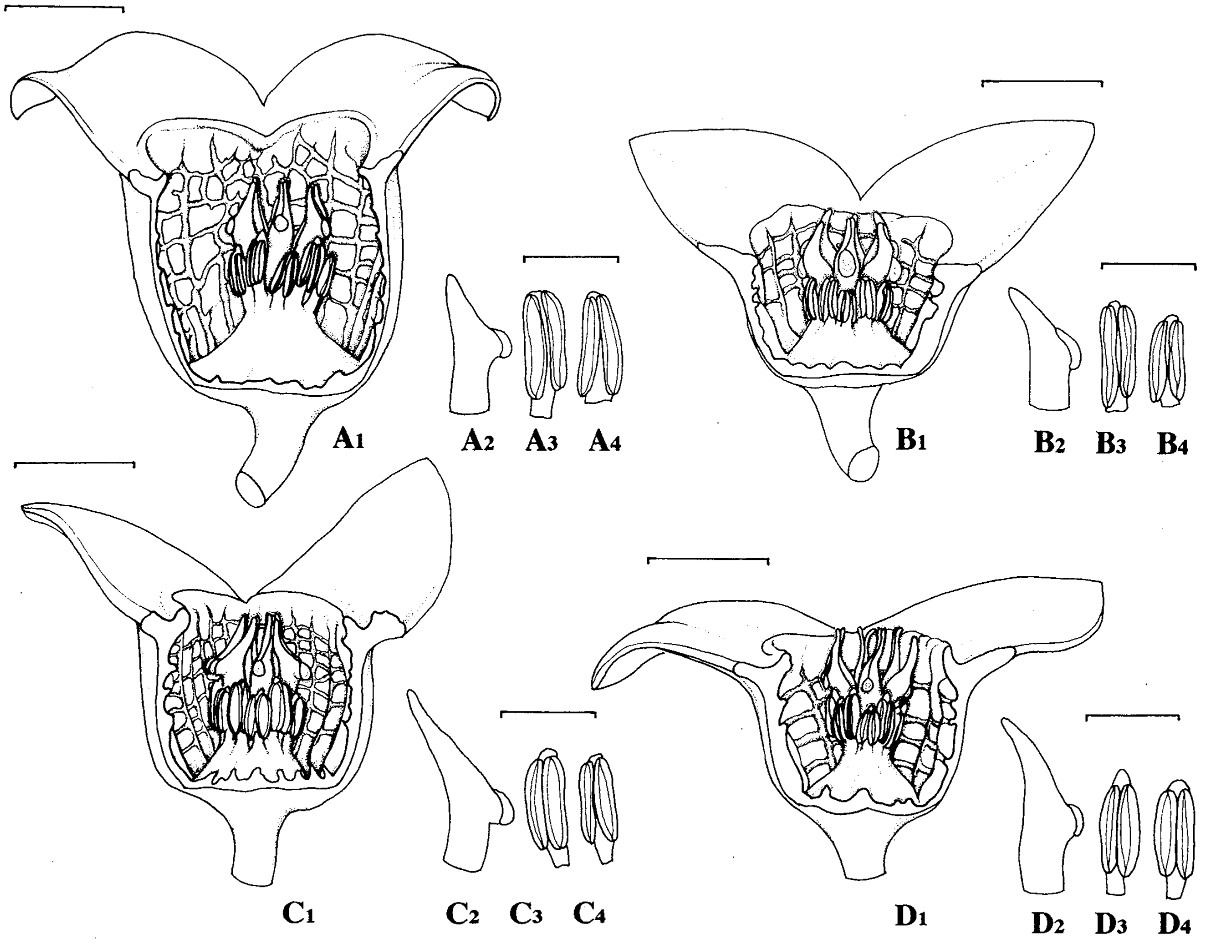

FIG. 3. Representative flowers of three taxa of *Asarum*, *A. majale*, *A. dilatatum*, and *A. fauriei* var. *takaoi*. A, *Asarum majale* from Mt. Fujiwara-dake; B, *A. dilatatum* from Mt. Nonobori; C, *A. fauriei* var. *takaoi* from Ogawa; D, *A. fauriei* var. *takaoi* from Osada. 1, flower, part of calyx removed (scale bar = 5 mm); 2, style with horn-like protuberance; 3, inner stamen (anthers dehisced); 4, outer stamen (anthers dehisced). Scale bar = 2 mm.

in factor loading), diam. of calyx tube entrance (+0.4279), length of anthers of outer stamens (+0.4211) and calyx lobe width (+0.4424) mainly contribute to the first component (PC-1); calyx tube length (+0.5996) contributes to the second component (PC-2); and length of stylar protuberance (+0.7313) largely contributes to the third component (PC-3, see Table 2).

A scatter diagram for the first (PC-1) and second (PC-2) principle components shows that plants of the May flowering *Asarum majale* from the Suzuka Mountains form a distinct group and are clearly separated from the others, although individuals assigned to *A. dilatatum* and *A. fauriei* var.

TABLE 2. Factor loading, eigenvalue, contribution, and accumulated contribution for principle components.

Character	Components		
	PC-1	PC-2	PC-3
Calyx-tube length	0.2831	0.5996	0.2391
Calyx-tube width	0.4842	0.2347	- 0.0224
Diameter of calyx-tube entrance	0.4279	- 0.2233	- 0.4437
Calyx-lobe length	0.3595	- 0.3850	0.3748
Calyx-lobe width	0.4424	- 0.4235	- 0.1833
Stylar-protuberance length	- 0.0015	- 0.3186	0.7313
Anther length of outer stamen	0.4211	0.3263	0.1912
Eigenvalue	3.04	1.65	1.34
Contribution (%)	43.5	23.6	19.1
Accumulated contribution (%)	43.5	67.1	86.2

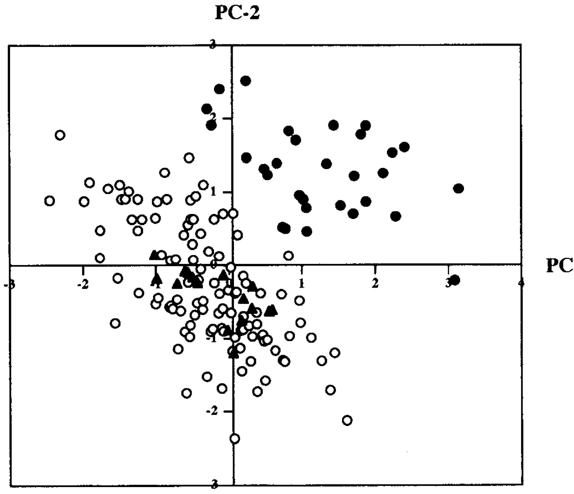

FIG. 4. Scatter diagram showing principle components 1 and 2 for 157 individuals from 14 populations of *Asarum majale* (●), *A. dilatatum* (▲) and *A. fauriei* var. *takaoi* (○).

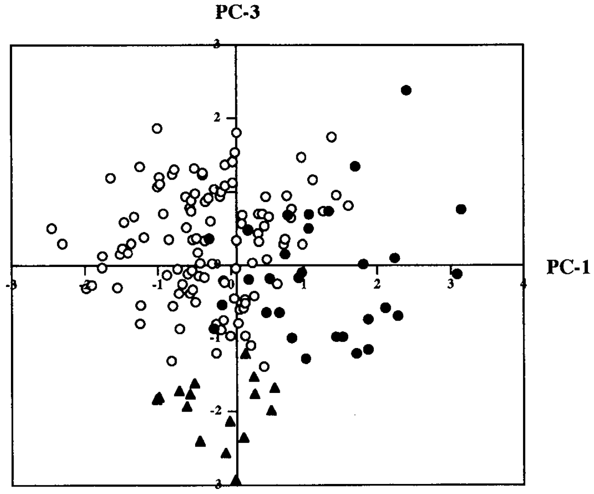

FIG. 5. Scatter diagram showing principle components 1 and 3 for 157 individuals from 14 populations of *Asarum majale* (●), *A. dilatatum* (▲) and *A. fauriei* var. *takaoi* (○).

takaoi are not separable from each other (Fig. 4). The scatter diagrams for the first (PC-1) and third (PC-3) principle components show that individuals assigned to *A. dilatatum* are nearly separated from the others by the third component, length of stylar protuberance (Fig. 5). The three taxa, *A. majale* (May flowering), *A. dilatatum* (autumn flowering) and *A. fauriei* var. *takaoi* (early spring flowering) can therefore be distinguished.

In comparing the mean value of ten morphological characters, including leaf characters, among the three taxa, the May flowering *Asarum majale* was significantly different from the other groups in length of calyx tube, width of calyx tube, length of stylar protuberance and length of anthers in the outer whorl of stamens (Table 3). *Asarum dilatatum* was significantly different from the others in calyx tube length, calyx lobe length, length of stylar protuberance and leaf blade length. *Asarum fauriei* var. *takaoi* significantly differed from the others in calyx tube length, diam. of the calyx tube entrance, length of stylar protuberance and number of longi-

TABLE 3. Mean values and standard deviations (S.D.) of nine morphological characters in three taxonomic groups of *Asarum* recognized by PCA. Letters (a, b, c) indicate significant differences at $p < 0.05$ by Steel-Dwass's multiple range test.

Character	Group of May flowering plants (=*A. majale*)		*A. dilatatum*		*A. fauriei* var. *takaoi*	
Calyx-tube length (mm)	8.8±1.0	a	4.7±0.5	b	5.8±0.9	c
Calyx-tube width (mm)	10.7±0.8	a	8.8±0.6	b	8.8±0.8	b
Diameter of calyx-tube entrance (mm)	7.2±1.0	a	7.8±0.7	a	6.2±0.9	b
Calyx-lobe length (mm)	8.1±1.2	a	6.8±0.6	b	7.9±1.4	a
Calyx-lobe width (mm)	10.0±1.5	a	10.2±0.9	a	9.3±1.5	a
Stylar-protuberance length (mm)	1.60±0.40	a	1.24±0.24	b	2.13±0.36	c
Anther length of outer stamen (mm)	2.16±0.26	a	1.61±0.15	b	1.68±0.21	b
Number of longitudinal ridges on inner surface of a calyx-tube	17.2±3.0	a	17.8±1.3	a	14.7±3.3	b
Leaf blade length (mm)	60.0±9.1	a	72.9±11.0	b	54.7±11.6	a
Leaf blade width (mm)	48.8±6.4	a	51.2±5.6	a	48.1±9.0	a

tudinal ridges on the inner surface of the calyx tube (Table 3).

Taxonomic consideration on Asarum majale

As stated above, three taxa of *Asarum, A. majale, A. dilatatum* and *A. fauriei* var. *takaoi*, were recognized by PCA. *Asarum majale* was not characterized by a particular floral character, but was distinguished from the others by a combination of several floral characters. Floral characters, such as the size of the calyx tube and stamen size, separated *A. majale* from *A. dilatatum* and *A. fauriei* var. *takaoi*. The stylar protuberances in *A. majale* are shorter and are not exserted from the calyx tube entrance (Fig. 3). Moreover, the three taxa differ from one another in flowering season.

Previously, *Asarum dilatatum* and *A. fauriei* var. *takaoi* were reported to occur on Mt. Fujiwara-dake and in adjacent areas (Murata 1982). Through field surveys and an examination of herbarium specimens deposited in KYO, MAK and TI we determined that only the May flowering *A. majale* is found in those areas. *Asarum majale* may, in fact, be allopatric with *A. dilatatum* and *A. fauriei* var. *takaoi*.

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